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FEEDING HABITS OF TEN SPECIES OF ORIBATID MITES (ACARI: ORIBATEI) FROM MALABAR, SOUTH INDIA

M. A. HAQ

Department of zoology, University of Calicut, Kerala, 673 635, India.

ABSTRACT

On the basis of food specificity of ten species of oribatid mites from litter samples collected from the grass and forest soils of Kerala, these species were grouped into three major feeding categories, namely mircophytophages, macrophytophages and panphytophages. Among species studied only *Oppia yodai*, *Hoplohorella scapellata*, *Lepidacarus ornatissimus* and *Galumna flabellifera orientalis* showed agreement in their aptitude for food substances in the laboratory and field conditions, whereas in the case of *Hoplophthiracarus siamensis*, *Torpacarus indicus*, *Liodes terrestris*, *Archegozetes longisetosus*, *Allonothrus giganticus* and *Galnmna longipluma* no such agreement could be observed. The four species in which agreement in feeding habits could be ascertained in the laboratory and field were further categorised into mycophages (*O. yodai*) and xylophages (*H. scapellata*). *L. ornatissimus* and *G. flabellifera orientalis* were noted to have wider range of food habits and hence were included under panphytophages. Evidence of microbial colonies aiding in biodegradation of plant matter was also detected from the guts of *T. indicus* and *A. giganticus* by faecal plating. Assessment of the enzymes (carbohydrases) capable of degrading plant materials in the gut was also attempted in *A. giganticus* and presence of maltase, cellobiase, raffinase and trehalase was detected, suggesting their involvement in the biodegradation of plant materials in the gut of these mites and thereby in their nutrition also.

INTRODUCTION

Every year a large quantity of litter is added into soil and the role of soil fauna in the decomposition of such plant materials and subsequent incorporation into the soil has been stressed recently by several investigators (Hayes, 1963; Littlewood, 1969; Wallwork, 1970; Edwards *et al.*, 1970; Hammad *et al.*, 1971; Kuhnelt, 1976; Tadros, 1976; Behan and Hill, 1978). Infection of litter by microbes produces a softening effect which would attract an array of microcommunities of varying complexities. Oribatid mites being the most abundant representatives of the soil mesofauna (Fujikawa, 1972; Wallwork, 1976; Mitchell and Parkinson, 1976; Crossley, 1977) appear to have beneficial effect in organic layers where they commonly occur. Evidences of earlier attempts have not been prompted on spot studies but laboratory observations on which one can depend, to some extent, would help to derive valuable information on the nutritional aspects of these mites.

Attempts to classify oribatids qualitatively by feeding experiments (Schuster, 1956: Wallwork, 1958; Hartenstein, 1962; Luxton, 1972; Haq and Prabhoo, 1977) have provided prompting guidelines on the behavioural responses of these mites to a variety of food substances. After an elaborate study of food specificity of oribatid mites from the Danish beech wood soil, Luxton (1972) revised the feeding terminology by adding new and minor feeding categories to microphytophages and macrophtophages. In the former he included mycophages, feeding on algae. In the latter he included phyllophages, feeding on leafy tissue and xylophages, feeding on woody tissue. His introduction of a term 'panphytophages' to non-specialized or indeterminate feeders was a combination of any of the feeding attributes mentioned above in which he could place maximum number of species he studied. The feeding effects of mites in relation to terrestrial decomposition was reviewed by Harding and Stuttard (1974).

On the basis of laboratory-cum-field data obtained from their study, Haq (1976) and Haq and Prabhoo (1977) categorized 20 species from Kerala soils and assessed the possible roles they play on litter decomposition. The present study is an attempt to elucidate the role of ten selected species, some of which have not been studied so far.

AREA SURVEYED AND SPECIES STUDIED

The soil of the study area is of laterite type with intermittent surface accumulation of litter in areas under plant cover. Mites were found concentrated in micro-pockets rather than distributed uniformly. Their abundance was felt only during monsoon when there was sufficient moisture in the soil. During this study, more than 20 species were identified and cultured but only half of them were finally taken into consideration for feeding experiments because others were few in number and found unhealthy in cultures. Of the 10 species subjected to study, *A. giganticus*, *A. longisetosus*, *G. flabellifera orientalis*, and *O. yodai* were obtained in great numbers. The population of other species, *L. terrestris*, *G. longipluma*, *H. scapellata*, *H. siamensis*, *L. ornatissimus* and *T. indicus*, though not high, were sufficient enough to complete the tests. Examination of the samples collected from different depths of the soil revealed the presence of *A. longisetosus*, *O. yodai*, *G. flabellifera orientalis* and *G. longipluma* in L layer. The feeding grounds of others could not be ascertained as they were in different organic horizons without uniformity in sampling times.

MATERIALS AND METHODS

Using a modified Tullgren funnel apparatus, a large number of adults could be separated from the soil and litter collected from the upper few centimeters of the study plots. The mites after having been separated were kept in small plastic dishes containing plaster of paris-charcoal mixture in the ratio 4:1. A range of 13 possible types of food material were provided for the first two days in order to determine

choice of feeding and checking starvation possibilities. When preference was noted for a particular food item, the mites were then isolated by species and each species was reared with its preferred food item for some days. For feeding tests, mites that survived best in the laboratory for a minimum period of one week, were considered. Care was taken to facilitate optimum culture conditions through frequent examintion with a minimum of three observations per day at regular intervals. Measurements of feeding rate was recorded by assessing the number of faecal pellets produced by a single individual per day as follows : 1–2=low preference, 2–4=moderate preference, and absence of faecal pellets was considered as instance of rejection.

For gut content examination 20–35 individuals of each species were dissected in glycerine. The contents were fixed in 80% ethyl alcohol, centrifuged and coloured with appropriate stains (Haq and Prabhoo, 1977). Following Sass (1959), Foster (1960), and Kuhnelt (1976) identification of the materials (Table II) from the gut was made. For faecal plating, live mites collected from the study field were transferred to sterile plastic containers after thorough washing. The faecal pellets laid by these mites were asceptically removed and plated in PDA medium (Booth, 1971) and nutrient broth medium to check the growth of fungal and bacterial colonies, respectively. Isolation and identification of fungi and bacteria were done immediately after their appearance.

For enzyme assays, 200 live *A. giganticus* were homogenized in 1ml of citric acid phosphate buffer (pH 6.1). The homogenate was centrifuged in the cold for 15 minutes. 100 μl each of the supernatant was pipetted into sterilized test tubes. The four substrates: maltose, cellobiose, raffinose, and trehalose were then pipetted into these tubes (100μl of a 1% w/v solution). A drop of toluene was added as a bacteriostatic agent. Heat inactivated enzymes along with substrates were included as controls in each case. The tubes were placed in an incubator at 37$\pm$ 1° for about 50 hr at the end of which 5 μl of the incubation mixture was spotted on a Whatman No. 1 chromatographic paper. All the possible end products of hydrolysis (glucose and galactose) as also the substrates were spotted in the same paper which was then developed in a solvent system of n-butanol, acetic acid and water (4:1:5) for about 48 hr (Partridge, 1948). The chromatogram, after drying, was sprayed with aniline diphenylamine phosphate reagents (Block *et al.*, 1958). It was then heated at 85°c for 10 minutes. The products of hydrolysis were identified by comparison with reference standards.

OBSERVATION AND DISCUSSION

Tables I and II provide information on the feeding habits of ten species of oribatid mites and their preference under laboratory and field conditions. From Table I it is evident that there is variation in food preference among the species studied. Except in the case of four species, *H. scapellata, H. siamensis, L. terrestris* and *O. yodoi*, all the other species could successfully complete their life cycles in the laboratory on the food substances offered, thereby permitting the study of the feeding

TABLE I.

Feeding behaviour of ten species of oribatid mites in the laboratory

	Brewer's yeast	Protococcus	Trichoderma sp.	Aspergillus flavus	Trichothecium roseum	Pestalotia sp.	Alternaria sp.	Agaricus	Pollen grains	Lichen	Moss	Decomposed leaves	Decomposed twigs	Remarks
1. *Hoplophorella scapellata*	—	—	—	—	—	—	—	—	—	—	—	+	+ +	Macrophtophage
2. *Hoplophthiracarus siamensis*	—	—	—	—	—	—	—	—	—	—	—	—	+	"
3. *Torpacarus indicus*	—	—	—	—	—	—	—	—	—	—	—	+	+ +	"
4. *Liodes terrestris*	—	—	—	—	—	—	—	—	—	—	—	—	+	"
5. *Lepidacarus ornatissimus*	—	—	+	—	—	—	—	—	—	—	—	+ +	+	Panphytophage
6. *Archegozetes longisetosus*	—	—	—	—	—	—	—	—	—	—	+	+ +	+	"
7. *Allonothrus giganticus*	—	—	—	—	+ +	+ +	+	—	—	+ +	—	+ +	+	"
8. *Galumna flabellifera orientalis*	—	+	—	—	—	—	+ + +	—	—	—	—	+ +	—	"
9. *Oppia yodai*	—	—	—	+ + +	—	—	—	—	—	—	—	—	—	Microphytophage
10. *Galumna longipluma*	—	—	—	—	—	—	+ +	—	—	—	—	—	—	"

+ + +/··· High preference + +/·· Moderate preference +/· Low preference — Rejection

TABLE II

Gut content analysis of ten species of oribatid mites

		Fungal hyphae	Fungal spores	Algal spores	Pollen grains	Leaf tissue	Wood tissue	Remarks
1.	*Hoploporella scapellata*	—	—	—	—	—	++	Macrophytophage
2.	*Hoplophthiracarus siamensis*	+	—	—	—	—	—	Microphytophage
3.	*Archegozetes longisetosus*	+++	+++	+	—	—	—	"
4.	*Allonothrus giganticus*	++	++	+	—	—	—	"
5.	*Oppia yodai*	++	+	—	—	—	—	"
6.	*Lepidacarus ornatissimus*	++	—	—	—	+	+	Panphytophage
7.	*Torpacarus indicus*	++	+	+	—	++	+++	"
8.	*Liodes terrestris*	++	++	+	+	—	+	"
9.	*Galumna longipluma*	+	++	—	+	+	+	"
10.	*Galumna flabellifera orientalis*	+++	++	+	+	—	+	"

+++ High preference ++ Moderate preference + Low preference — Absence

habits of the immatures of these species also. Dietary difference noted among these species have enabled their categorisation into specific feeding groups in general as suggested by earlier investigators (Wallwork, 1958 ; Luxton, 1966, 1972; Haq and Prabhoo, 1977, Schatz, 1979). Among the ten species studied under laboratory conditions, macrophytophages *(H. scapellata, H. siamensis, L. terrestris* and *T. indicus)* and panphytophages *(L. ornatissimus, A. longisetosus, A. giganticus* and *G. flabellifera orientalis)* constituted 40% each, and microphytophages *(O. yodai* and *G. longipluma)* constituted the remaining 20%. On the contrary, from gut content analysis, only 10% of the species could be designated as macrophytophages *(H. scapellata)*, 50% as panphytophages *(L. ornatissimus, T. indicus, L. terrestris, G. longipluma* and *G. flabellifera orientalis)* and the remaining 40% as microphytophages *(H. siamensis, A. longisetosus, A. giganticus* and *O. yodai)*. Therefore a difference of 10%, 20% and 30% variation between laboratory and field conditions could be observed in panphytophages, microphytophages and macrophytophages respectively. The above variation indicates that among the three main feeding categories, panphytophages species are more adapted to variations in food types than the other two types. These obesrvations show that laboratcry feeding preferences do not always necessarily reflect their natural feeding tendancy as these mites have access to diverse food items in their natural habitat, unlike the selected food items given in the laboratory. On the basis of the results obtained, it is possible to categorise the species studied into a) members showing a restricted feeding habit, b) members showing a wide range of feeding habit and c) members showing a feeding habit in between the above two types. *H. siamensis, L. terrestris, O- yodai* and *C. longipluma* showed restricted food preference to the food substances offered in the laboratory, limiting their preference to one item each, whereas *A. giganticus, L. ornatissimus, G. fiabllifera orientalis* and *A. longisetosus* showed choice of more than one food item.

Results obtained from the laboratory feeding habits of the above ten species were compared with the gut content analysis of field populations. This was done

Fig. 5. Adults of *A. longisetosus* feeding on parenchyma of *Artocarpus* leaving peripheral veins.

Fig. 6. Adults of *G. longipluma* nibbling on fungal encrustations on decomposed wood.

Fig. 7. Adults (both newly emerged and old) of *G. flabellifera orientalis* feeding on *Alternaria* sp. of fungus.

Fig. 8. Adults of *T. indicus* on partly decomposed twig.

Fig. 9. Channels produced at the inner portions of the twig by the feeding activity of *T. indicus.*

Fig. 10. Faecal pellets produced by *T. indicus* feeding on soft wood.

Fig. 11. Tunnel formation on twigs by *T. indicus.*

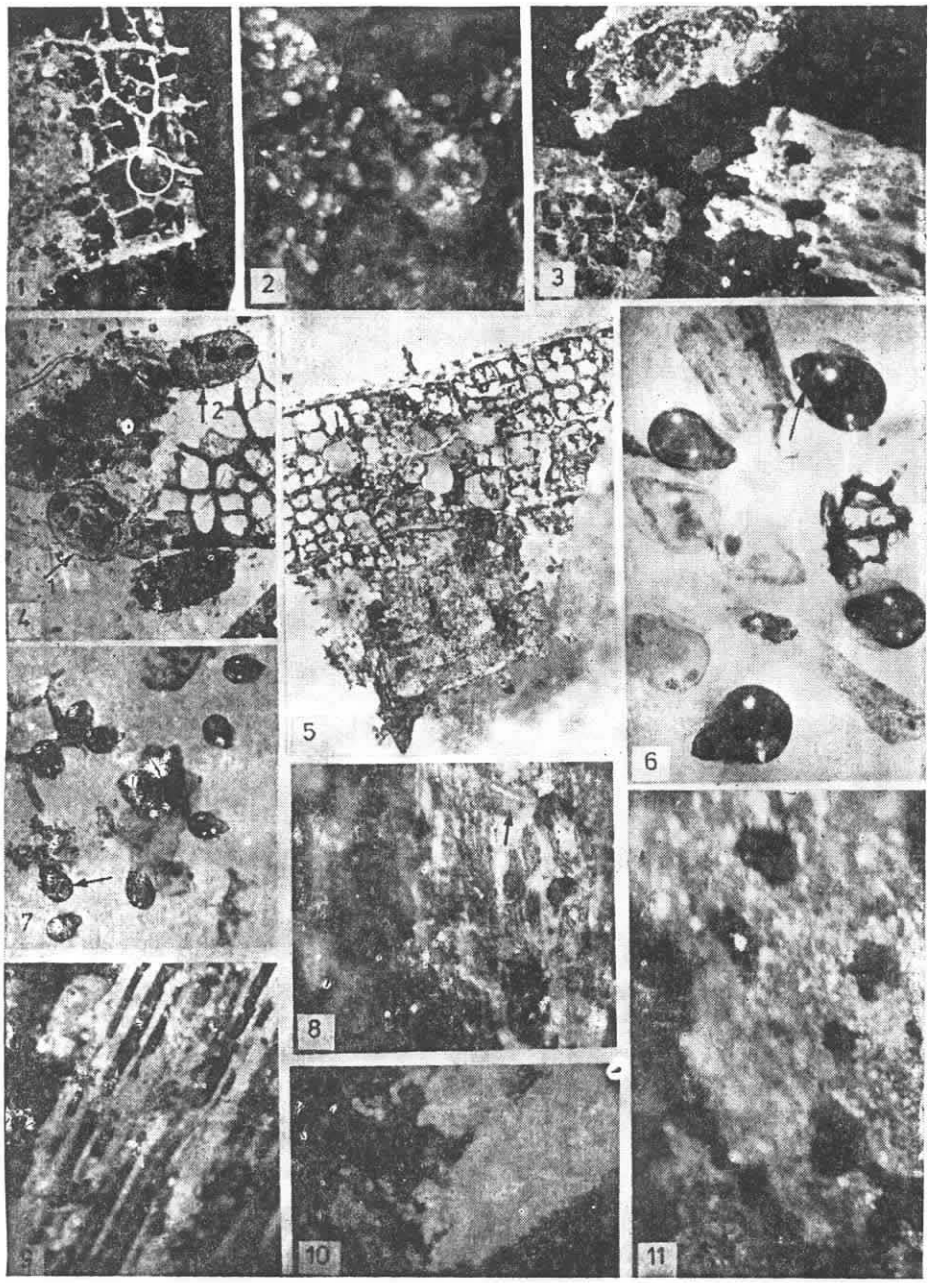

Fig. 1. Active feeding of *L. ornatissimus* on decomposed leaf.
Fig. 2. Faecal pellets produced by *L. ornatissimus* feeding on bamboo leaves.
Fig. 3. Portions of twigs and barks after feeding by immatures of *L. ornatissimus* (Note the pits and faecal pellets produced)
Fig. 4. Active feeding adults of *H. siamensis* and *L. ornatissimus*.

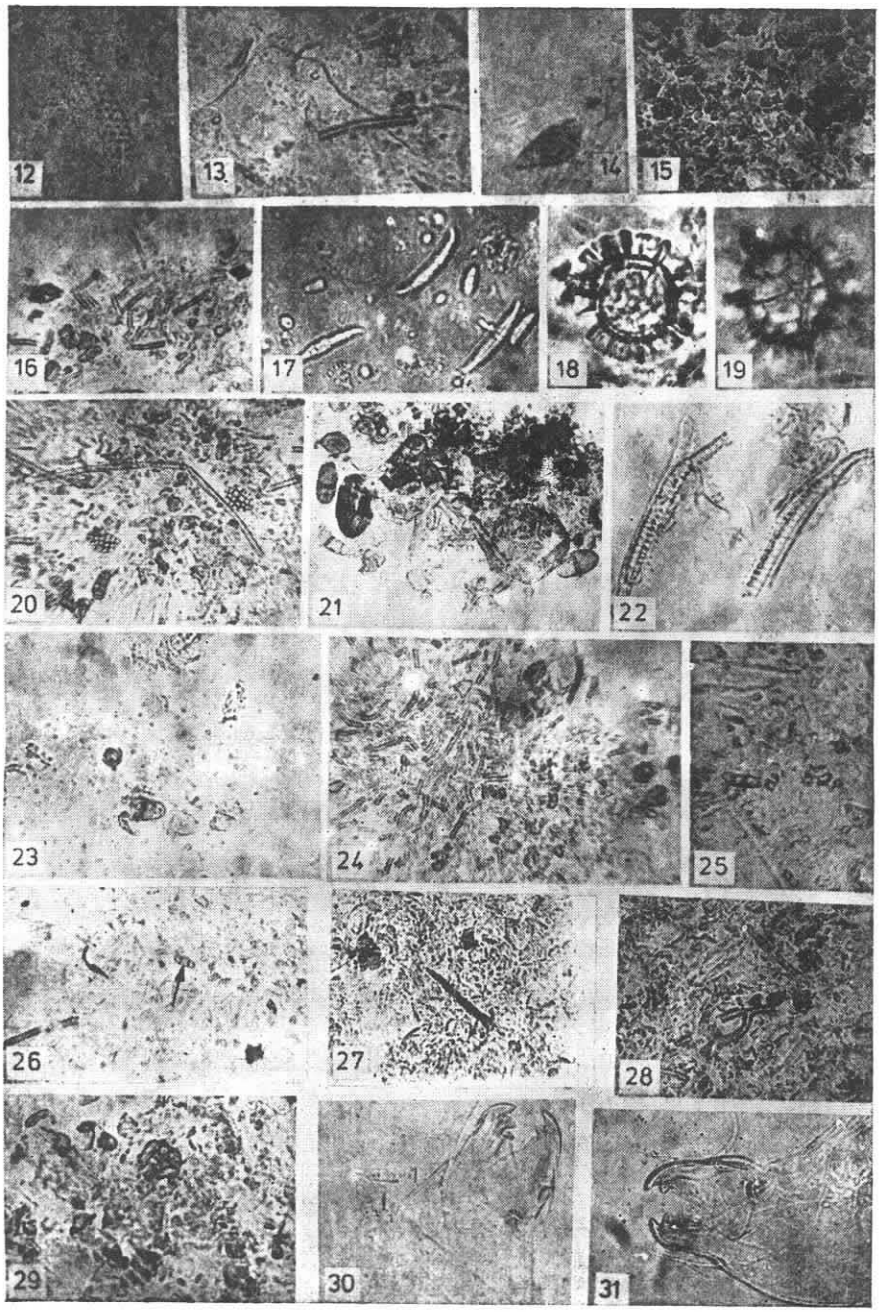

Fig. 12. Pitted xylem vessel from *H. scapellata*.
Fig. 13. Fungal hyphae from *H. siamensis*.
Fig. 14. Masticated hyphae and spores of *Curvularia lunata* from *L. terrestris*.
Fig. 15. Algal spores from *L. terrestris*.
Fig. 16. Fungal hyphae from *O. yodai*.

mainly to check the correlation, if any, existing in the feeding habits of these species between laboratory and natural habitat. *L. ornatissimus*, a rare species collected from bamboo litter, was found actively feeding on dicot leaves (Fig. 1,4) or various stages of decay in the laboratory, producing large number of faecal pellets (Fig. 2). The voraciously feeding immatures, though sluggish, fed heavily on twigs and barks (Fig. 3). The preference for leaves by adults was confirmed from gut content examination by the occurrence of leaf portions with spiral thickenings (Fig. 22). The two xylophagous species *H. scapellata* and *H. siamensis* were found devouring different types of woody tissues (Fig. 4) in the laboratory. The chelicerae of the species when examined were found provided with well pronounced and strong teeth (Fig. 31) suited for such a diet as noted by Dinsdale (1974a). While the gut of *H. scapellata* contained remants of pitted xylem vessels (Fig. 12) alone that of *H. siamensis* showed rare occurrence of fungal hyphae (Fig. 13) also. Probably these fungal hyphae would have been present on the woody tissue fed by this mite. The few individuals obtained for gut content analysis did not possess positive evidence of wood feeding in nature, as materials in their faecal pellets were in an advanced stage of decomposition.

Adult of *A. longisetosus* when supplied with partly decomposed leaves of *Artocarpus* was found to devour the parenchyma tissue extensively leaving the peripheral veins (Fig. 5). But in the field, they were found to have fed on ascospores, fungal hyphae and guard cells (Fig. 24), spores of *Septonema* sp. (Fig. 25) and leaf remains. In the laboratory hundreds of immatures of *A. longisetosus* were found consuming fungal matter unlike the adults which may be partly due to their ill developed mouth parts.

The two active galumnoid species, *G. longipluma* (Fig. 6) and *G. flabellifera orientalis* (Fig. 7) were mycophagous and panphytophagous respectively in the labora-

Fig. 17. Spores of *Fusarium* sp. of fungus from *O. yodai*.
Fig. 18. Pollen grain from *G. longipluma*.
Fig. 19. Pollen grain from *G. longipluma*.
Fig. 20. Fungal hyphae and spores from *G. longipluma*.
Fig. 21. Spores of *Botryodiplodia theobromae* from *G. flabellifera orientalis*.
Fig. 22. Leaf portion showing spiral thickening from *L. ornatissimus*.
Fig. 23. Remnants of perforation plate of vessel member from *T. indicus*.
Fig. 24. Partly digested ascospores and fungal hyphae from *A. longisetosus*.
Fig. 25. Spores of *Septonema* sp. from *A. longisetosus*.
Fig. 26. Spores of *Torula* sp. from *A. giganticus*.
Fig. 27. Trichomes from *T. indicus*.
Fig. 28. Osteosclerites from *T. indicus*.
Fig. 29. Leaf remains showing guard cells from *A. longisetosus*.
Fig. 30. Chelicera of *T. indicus*.
Fig. 31. Chelicera of *H. scapellata*.

tory. A variety of five food items like pollen grains (Figs. 18 and 19), fungal hyphae, spores (Fig. 20), leaf and woody tissues could be detected from the gut of *G. longipluma*. Similarly the gut of *G. flabellifera orientalis*, also showed five different types of food, but instead of leafy tissue in the former algal spores were found in the latter with same preference. Large number of partly digested and intact spores of *Botryodiplodia theobromae* (Fig. 21) could be identified from the gut of *G. flabellifera orientalis*. Among the ten species subjected to the present study, *A. giganticus* was noted particularly for its wide choice of food items in the laboratory and for its preference to lichen. Adults of this species responded to three species of fungi, lichen and two types of higher plant materials. With the exception of *Alternaria* sp. of fungus, all the food items were found accepted by the immatures as in the case of the adults. A fungal diet consisting of three species, though found accepted by the adults, their gut content revealed the presence of *Torula* sp. (Fig. 26), a different species of fungus together with a large number of algal spores.

Rearing of *L. terrestris* in the laboratory was difficult since it rejected most of the food items except a casual response, to woody tissue. In nature its choice was mainly to fungal species among which hyphae and spores of *Curvularia lunata* was dominant (Fig 14). Few adults collected during rainy season when dissected for gut contents were found filled with algal spores (Fig. 15). Though *O. yodai* was recognised to be strictly mycophagous both in the laboratory and field, there was difference in the fungus species preferred. Of the five species of fungi provided in the laboratory it preferred *Aspergillus flavus* which was found rejected by all the other species in the present study. Examination of the gut content of the same species revealed the presence of fungal hyphae (Fig. 16) and spores of *Fusarium* sp. (Fig. 17).

Laboratory preference of *T. indicus* (Fig. 8) was confined to higher plant materials only. When twigs were provided in the laboratory, the mites started feeding on them, making holes (Fig. 11). At the inner portion of these twigs were seen channels often packed with faecal pellets produced by the feeding activity of these mites (Fig. 9). These crevices offered suitable habitat for oviposition and dovelopment of immatures. Gradually the twigs were completely triturated with the help of well developed chelicerae bearing pronounced teeth (Fig. 30), leaving finally a mass of faecal pellets only. When brownish twigs were provided as food the colour of the faecal pellets was brown and when white woody tissues were consumed, the colour of the faecal pellets was white (Fig. 10). The presence of perforation plate of vessel member (Fig. 23) indicates its feeding on woody tissue. Trichomes (Fig. 27) which are epidermal extensions and osteosclerites (Fig. 28) also were identified from their gut. The feeding habits of their immatures, in most cases, were found similar to those of adult. However, in some species *(A. longisetosus)* difference could be noted. In the case of *A. giganticus* even the different stages exhibited differing food preference in the laboratory. Larvae and early nymphs of this species, on innumerable

observations were seen repeatedly crowding and feeding on yeast pellets. But late nymphs were often found feeding on *Trichothecium roseum* and *Pestalotia* sp. of fungus. This food item was found favouring the mite to complete several generations successfully in the laboratory.

The similarity noted between the feeding habits of immatures and adult of *L. ornatissimus* can be attributed to their sole preference to leafy material. From this it is evident that preferred food enhances reproduction. The presence of fungal hyphae even in gut of strictly xylophagous species may rather be incidental than intentional as exemplified by *H. siamensis* in the present study. The failure of xylophagous species, *H. scapellata* and *H. siamescis* to reproduce in the laboratory may be due to the fact that the wood species provided may not be the right type of food needed for their growth and reproduction. The case of differing feeding preference noted between the immatures and adult of *A. longisetosus* may be due to the poorly developed mouth-parts for cutting and chewing purposes. Pande and Berthet (1973) did not find any such difference in the feeding habits of immatures and adults they studied. However, difference in food preference between immatures and adult are reported by Sengbusch (1954), Wallwork (1958), Kuhnelt (1976), Woodring and Cook (1962) and Luxton (1966). The two galumnoid mites, *G. longipluma* and *G. flabellifera orientalis* were found very active devouring a variety of food substances in the field. Evidences were also gathered for the presence of this species in a variety of ecological conditions also. Perhaps the active nature of these mites may be helping them to explore wider areas for food selection. Their occurrence in similar habitat may also account for their similar feeding trends as evidenced from their gut content analysis.

The body of *G. flabellifera orientalis* are often found carrying spores of various fungal species which would reflect their role as a fungal carrier. A few instances of occurrence of cysticercoids in the body cavity of *G. flabellifera orientalis* are noted which indicates its role as a vector. *A. giganticus* was the most sluggish of the species studied here, showing a fair choice for fungal rich habitats which confirms is fungivorous habit. As in the case of *G. flabellifera orientalis*, this species is also found to have a prominent role in disseminating fungal spores and hyphae. The role of oribatid mites as fungal carriers is also reported by Jacot (1930), Reddy *et al.* (1978) and Behan and Hill (1978). The very reluctance for feeding any of the food items provided and consequent death of many individuals of *L. terrestris* would suggest that none of the food items provided in the laboratory may be their preferred diet. *O. yodai*, though confirmed as a strict mycophagous species both in the laboratory and field, did not reproduce in the laboratory. Perhaps the fungal species provided in the laboratory were not its preferred diet.

The two lohmanniid species *L. ornatissimus* and *T. indicus* were macrophyto-phagous in habit producing a high effect on the food materials they selected. The voracious feeding tendency of nymphs and adults of *L. ornatissimus* on leafy material

and of *T. indicus* on woody material resulted in rapid trituration of the leafy and woody materials provided for them. The powerful chelicerae of these species are found well adapted for comminution of the materials resulting in the final conversion of the whole food material. This has resulted in the accumulation of large quantities of faecal pellets in the culture vessels. This strongly supports the positive involvement of these species in the disintegration of plant matter.

Results of laboratory and field observations on these mites provided some clues regarding their distribution in different soil profiles. The two phthiracarid mites, *H. scapellata, H. siamensis* and their nymphs, were collected from decomposed twigs and soft wood pieces in the field. This revealed that they were confined to the surface layer (L layer) of the soil. Though the two lohmannid species were also inhabitants of the litter layer, the migration to the adjacent layers appeared to be little more elaborate since their adults and nymphs could be collected from the litter and humus layers (L, F and H layers) also. Regarding the habitats of *A. longisetosus* and *A. giganticus,* it can reasonably be concluded that they occuppy isolated ecological pockets where decomposed leaves with associated fungal colonies are abundant. The former species is confined more towards the surface layer whereas the latter species is confined to deeper layers. The two galumnoid species were found not confining to any layer in particular but showing random distribution. *O. yodai* was found more in F and H layers with rare occurrence in L layer also.

The detection of α glucosidase. β glucosidase and α galactosidase activities point to capacity of *A. giganticus* to digest plant materials. The detection of trehalose would further explain the ability of this species to degrade fungal matter, trehalose being a major component of fungal material (Dinsdale. 1974 b). Laboratory experiments have shown that this animal thrives well on fungal material also. Therefore, it is interesting to note that this species is equipped with an enzyme complement capable of decomposing plant material when fed on this and enzyme capable of decomposing fungi when fed with fungal matter. The microbial analysis from the gut has shown the presence of two types of cellulolytic bacteria. It is not certain whether the enzymes detected from this species are produced by the animal per se or by the gut. It is likely that the gut symbiont can adapt themselves to the food materials and synthesize enzymes specific for the digestion of that particular food matter. However, an extension of this work on these lines is necessary to confirm this.

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